

COMPARISON OF TEMPORAL REALISTIC TELECOMMUNICATION BASE STATION EXPOSURE WITH WORST-CASE ESTIMATION IN TWO COUNTRIES

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Running title: Temporal realistic exposure

Acknowledgement: W. Joseph is a Post-Doctoral Fellow of the FWO-V (Research Foundation–Flanders).

Abstract- The influence of temporal daily exposure to Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications Systems (UMTS-HSDPA) is investigated using spectrum analyzer measurements in two countries, France and Belgium. Temporal variations and traffic distributions are investigated. Three different methods to estimate maximal electric field exposure are compared. The maximal realistic (99%) and the maximal theoretical extrapolation factor used to extrapolate the measured Broadcast Control Channel (BCCH) for GSM and the Common Pilot Channel (CPICH) for UMTS are presented and compared for the first time in the two countries. Similar conclusions are found in the two countries for both urban and rural areas: worst-case exposure assessment overestimates realistic maximal exposure up to 5.7 dB for the considered example. In France, the values are the highest, because of the higher population density. The results for the maximal realistic extrapolation factor at the weekdays are similar to those from weekend days.

Key Words- temporal exposure, electromagnetic fields, radio frequency, general public.

I. INTRODUCTION

People are continuously exposed to radio frequency (RF) electromagnetic fields emitted by wireless communication systems and broadcasting systems (both television and radio). Human exposure has to be assessed in accordance with international guidelines. This evaluation cannot be limited to a single measurement moment and should account for temporal variations of RF electromagnetic field exposure. The International Commission on Non Ionizing Radiation Protection⁽¹⁾ and the Institute of Electronics and Electrical Engineers

IEEE⁽²⁾ recommended exposure guidelines. Standards have also been developed to check the compliance with limits like those from the European Committee for Electro-technical Standardization CENELEC⁽³⁾ and the International Electrotechnical Commission (IEC) and form IEEE⁽²⁾.

The CENELEC method proposes to check the compliance to the reference levels, by extrapolating an instantaneous measurement of the pilot signals strength to the “worst-case” values. The worst-case assessment is adopted by some countries to ensure reliable and reproducible exposure assessments in varying traffic conditions, which guarantees the compliance. However, the extrapolation to maximum traffic does not consider the actual real-live exposure induced by the fluctuations of the field strength during communication.

Temporal variations and measurement procedures for temporal exposure assessment of RF signals are investigated in refs (3, 4, 5, 6, 7, 8). In ref (7), the daily distribution of the RF field strength is determined for FM Broadcasting (FM), Television (TV), Global System for Mobile Communications (GSM900 at 900 MHz and GSM1800 at 1800 MHz), Universal Mobile Telecommunications Systems (UMTS), and High Speed Downlink Packet Access (HSDPA) services. The proposed method gives to the different signals a conservative extrapolation factor to determine the maximum real exposure during a day using a statistical method on different measurements performed over 24h. Erlang data, representing average mobile phone traffic intensity during a period of time, is related to RF exposure using temporal measurements during a week in ref (6). Diurnal variations of fields of mobile telecommunication and broadcasting systems are studied in Greece (5). Data from surveys of radio base stations in 23 countries from the year 2000 onward is pooled to investigate

chronological trends and compare exposures by technology⁽⁸⁾. Daily variations are not accounted for in ref (8).

The objectives and novelties in this paper are the following. Firstly, we estimate the maximum exposure in two countries (Belgium and France) in urban and rural zones by comparing the extrapolation methods of^(6, 7) and CENELEC⁽³⁾ for the first time. Secondly, we determine the maximal *realistic* (99%) and the maximal theoretical extrapolation factor used to extrapolate the measured Broadcast Control Channel (BCCH) for GSM and the Common Pilot Channel (CPICH) for UMTS/HSDPA and the comparison in two countries. Thirdly, for the determination of the realistic extrapolation factors, we distinguish here between GSM900, GSM1800, UMTS, and HSDPA, and two types of environments (urban and rural), and weekdays versus weekend days, which is novel. Fourthly, the methods to assess the electric field exposure at a time instant from the electric field measurements at another time instant, and to estimate the maximum electric field value over a day are compared. The first method (Erlang method⁽⁶⁾) is based on the Erlang data for GSM signals and on the throughput data or transmitted power for the UMTS signals. The second method (3-Gaussian method⁽⁷⁾) is based on a statistical analysis using a three-Gaussian distribution model. The third method is the one of CENELEC⁽³⁾ to extrapolate to maximal field values.

II. MATERIALS AND METHOD

A. *Configurations and measurement setups*

In Belgium, the electric fields are measured with a tri-axial R&S TS-EMF Isotropic Antenna (dynamic range of $1 \text{ mV m}^{-1} - 100 \text{ V m}^{-1}$ and a frequency range of $30 \text{ MHz} - 3 \text{ GHz}$)

in combination with a spectrum analyzer SA of type R&S FSL6 (frequency range of 9 kHz – 6 GHz – <http://www2.rohde-schwarz.com/>). To demodulate the UMTS and HSDPA signals, the FSL-K72 decoder option of the R&S SA is used. Using this option, the code domain analyzer can be used for demodulation of the UMTS signals. The tri-axial antenna has a built-in switch to select the appropriate axis during the measurements.

In France, the measurement equipment consisted also of a spectrum analyzer (Agilent MXA, N9020A model, frequency band: 20Hz-13.6 GHz, www.agilent.com), an isotropic tri-axial probe satisfying the specifications of the EN50492 standard⁽³⁾, a switch that selects the axis of the probe to the measured unit, and a laptop controller to control the analyzer and the switch, and to save all the measurements. For UMTS (3GPP R99) and HSDPA systems, a Wideband-Code Division Multiple Access (W-CDMA) decoder (Anritsu, ML8720B model, www.anritsu.com) is used for measurements to extract the total power and also the allocated power to each channel which is not possible with a standard spectrum analyzer.

The measurement systems in both studies are thus very similar: these consist of narrowband equipment i.e., a spectrum analyzer and suitable measurement probes. In both studies also a W-CDMA decoder is used to extract the power allocated to each channel. These measurement setups have been validated extensively in previous studies^(4, 6, 7) and satisfy the CENELEC standard⁽³⁾, thus they are comparable. The main difference between both studies is that in Belgium, we had collaboration of the mobile operators, so the contribution per operator could be determined. The measurement uncertainty for the electric field is ± 3 dB for the considered SA setup⁽³⁾. This uncertainty represents the expanded uncertainty evaluated using a confidence interval of 95%.

B. Measurement procedure

Fig. 1 summarizes the measurement procedure for the temporal assessment of RF base station exposure in Belgium and France.

In Belgium, 16 sites were considered, 7 sites in rural environments and 9 in urban environments (11 outdoor sites and 5 indoor sites). The sites were investigated during 2 different measurement campaigns. A first measurement campaign was performed in Brussels, Belgium; long-term temporal measurements were performed here during 7 days for 2 sites in rural zones and 3 sites in urban zones. Additionally, in Flanders, Belgium, 5 sites in rural zones and 6 sites in urban zones were investigated during 2 weekdays and 2 working days.

For all the sites, a spectral overview measurement (step 1 in Fig. 1) in the frequency range of 80 MHz up to 3 GHz has been performed to identify present RF signals. Based on this spectral overview the relevant present signals (FM, GSM900, GSM1800, HSDPA, UMTS and demodulation of the UMTS-HSDPA signal for the different operators in Belgium) were selected for the long-term measurements (step 2). These significant signals were measured sequentially for each of the three orthogonal components and each measurement sequence was repeated during several days (step 3). Depending on the number of significant signals, a measurement sequence took about 2-4 minutes. Performing these measurements during 7 and 4 days resulted for each significant signal in a total of 2,520 and 1,440 samples, respectively. The total number of time samples was 115,967 for urban zones and 100,419 for rural zones. In Belgium, three different operators are active for commercial GSM and UMTS networks. For the measurements and the statistical analysis, the signals for the different operators were processed separately for each kind of signal (e.g., GSM900, GSM1800 ...).

In Paris, France, 6 measurements at 3 different sites in rural zones and 22 measurements in 9 different sites in urban zones were performed. Also, first a spectral measurement (step 1 in Fig. 1) was performed to identify present RF signals (step 2). Measurements were performed with a sampling rate of 10s for each site in different locations (bedroom, kitchen, living-room) to obtain a wide range of situations (step 3). Each of these measurements resulted in a total of 8,570 measured samples per signal during one day. The total number of time samples was 51,420 per signal for rural zones and 188,540 per signal for urban zones. For UMTS and HSDPA systems, 8 measurements for UMTS and 12 measurements for HSDPA were performed with a sampling rate of 6s in 5 different sites in urban areas. For each measurement a total of 15,000 measured samples was obtained during one day.

Different factors can influence the RF measurements (path loss, the data rate, discontinuous transmission (DTX), power control...). This has been addressed in previous publications by making network adaptations to enable that research^(9, 10). Note that in this paper, the measurements were performed continuously during 24 hours to take into account all these aspects. The networks were not forced to operate in a specific mode in order to observe traffic variations in real conditions. From the obtained data the maximal exposure factors can be assessed (Fig. 1).

C. Method to assess realistic maximal extrapolation factors

The 3-Gaussian method⁽⁷⁾ is compared with the CENELEC extrapolation method⁽³⁾ to estimate the maximum exposure in two countries (Belgium and France). Both methods are based on the determination of the extrapolation factor to use in combination with the pilot signals. Basically, GSM and UMTS-HSDPA are signals composed of two parts. The first part

consists of the pilot signals. The second part consists of the traffic signals. BCCH and the CPICH are the pilot signals for GSM and UMTS-HSDPA respectively. BCCH and CPICH represent the signalizations and they are continuously emitted over the day.

To extract the broadcast control channel BCCH for GSM using spectral measurements the following method is used. Spectral scans in the appropriate GSM frequency band enable to identify the different GSM channels. The BCCH signals can be identified because these never become zero, in contrary to the TRX signals that vary largely between zero (no phone traffic) and maximal field values (lots of traffic)⁽⁴⁾. Moreover, for hopping (i.e., changing the channel frequency with time) the frequencies of the hopping channels are known or provided by the mobile operators. Fig. 2 shows as an example the frequency spectrum (hopping) for a GSM900 signal measured during 24 hours in Belgium. Fig. 2 shows 396 traces of momentary measurement values of the electric field captured with the SA: clearly 4 BCCH channels and various traffic (TRX) channels (vary from noise level to maximal values) can be separated in the downlink band. For UMTS-HSDPA, the measurements occurred with a code domain analyzer (see Section measurement setup) where the CPICH and traffic channels are extracted. Again, BCCH and CPICH signals never become zero in contrary to the electric-field strength of the TRXs⁽⁴⁾.

In theory, the BCCH and CPICH power remains constant but in-situ the electric field strengths of the BCCH and CPICH vary over time due to environmental changes (e.g., movement of people and cars, weather) and instability of the BCCH⁽⁶⁾. The traffic variation is represented by the ratio ($N_{\text{traffic}}(t)$) of the total power ($P_{\text{total}}(t)$) to the pilot power (P_{pilot}) as follows:

$$N_{traffic}(t) = \frac{P_{total}(t)}{P_{pilot}}. \quad (1)$$

With t representing time (s).

Some standards^(3, 12) propose an extrapolation method to assess the maximal “worst-case” electric field, based on the measurements of the pilots signals. Network operators can provide the maximal theoretical value of the traffic channels. Extrapolation using these numbers often overestimates the realistic electric-field values because traffic channels vary during the day and these numbers represent the maximal capacity of the cell. For control agencies, it is important to extrapolate using *realistic* extrapolation factors to check compliance with limits.

In this paper, N_{TRX} and N_{CPICH} are the equivalent traffic ($N_{traffic}$ in (2)) evaluated for GSM and UMTS, respectively. Note that the maximum numbers of traffic (TRXs) channels (and CPICHs) are set by telecommunication operators through radio planning optimization taking into account the population density and the traffic capacity. Systems are also designed to avoid a maximum load to allow a good traffic quality.

In France, the maximum number of TRXs has been defined by national authorities as a constant value depending on the population density and in practice this represents 99% of the actual installed cases. The values of the maximum deployed TRXs by operators for GSM900 and GSM1800 networks are 6 and 8, respectively. These maximum values have been recommended by the National Agency of Frequency (ANFR)⁽¹¹⁾ to assess the exposure for maximum traffic situation (worst case). In^(13, 14), the value of 10 is recommended for N_{CPICH} in UMTS network, which corresponds to the maximum theoretical value (recommended also by ANFR). There is no value recommended yet for N_{CPICH} in HSDPA systems.

In Belgium, the different regional regulations do not include any attempt to extrapolate to the maximum exposure. The electric-field values averaged over 6 minutes have to be compliant with regional limits at each moment of the day, but no further details are included.

In this study, the determination of the real number of equivalent TRXs and CPICHs (N_{TRX} and N_{CPICH}) that is active over one day in France and in Belgium using the method proposed in⁽⁷⁾ is presented. To find the realistic maximum number of TRX-CPICH values, the 99% value is taken for each measured signal. For the measurements in Belgium, the 99-percentile value of the TRX-CPICH is evaluated for each site and for each operator. This is not the case for the measurements in France, where only one model and one TRX-CPICH value (max at 99%) is available for each technology because all the measurements for one technology were processed together.

D. Summary of existing methods for extrapolation self

The CENELEC method⁽³⁾ proposes to check the compliance to the reference levels, by extrapolating an instantaneous measurement of electric field strength of the pilot signals (BCCH and CPICH) to the “worst-case” value. This method does not allow determining the electric field exposure at a time instant from the electric field measurements at another time instant. Therefore, new methods are needed to evaluate the real exposure.

In^(4, 6), a method is proposed to calculate the maximal electric field strength during 24 hours (1 day) from the momentary total measured electric field value (pilot signals and traffic signals together) using the corresponding Erlang data for GSM. The maximal electric field strength ($E_{\text{calc}}^{\text{max}}$) can be calculated from a momentary field value $E_{\text{norm}}(t)$ using eq. (2).

$$E_{calc}^{max} = E_{mom}(t) \frac{\max(Erlang)}{Erlang(t)} = E_{mom}(t) SF_{Erlang}(t) \cdot (V / m) \quad (2)$$

With $Erlang(t)$ and $\max(Erlang)$ are the Erlang data at time instant t and the maximum Erlang data during 24 h for the corresponding electric field value of the GSM signal at a specific location, respectively. SF_{Erlang} is the normalized Erlang data as function of the time. Fig. 3 shows the median value of all the normalized Erlang data as function of the time between 9:00 am and 6:00 pm for the different considered sites provided by the telecom operators (15 data sets for GSM 900 and GSM1800, Section II.A). The chosen time interval corresponds to typical working hours during which control agencies can make their measurements. One has to remark that the traffic data must be provided by the operator. In this paper, this method is applied for GSM because only the Erlang data was provided. For UMTS/HSDPA no traffic data was available.

In⁽⁷⁾, the method proposes to obtain the $N_{TRX}(t)$ over 24 hours. Based on the explanation of Section II.C, this factor is found with a statistical method on different measurements performed at different sites. This factor can be used whatever the location of the performed measurements. The scaling factor $SF_{3-Gaussian}$ is defined as follows:

$$SF_{3-Gaussian} = \frac{E_{max}}{E(t)} \quad (-) \quad (3)$$

(-) representing no unit. Fig. 3 shows also the scaling factor using eq. (3) obtained using the data presented in this paper. In the following, N_{TRX} and N_{CPICH} will be determined for realistic circumstances in the two countries.

III. RESULTS AND DISCUSSION

A. Comparison of realistic maximal exposure

A summary of the median and maximum values of the realistic extrapolation factors (N_{traffic} in eq. (1), 99-percentiles) for the different technologies is provided in Table 1. In this table, the theoretical maximum values for France are those recommend by ANFR; the theoretical maximal values for the measured sites were not available. For the measurements in Belgium, the theoretical maximum values are these provided by the network operators for the corresponding sites. The 99-percentile values of N_{TRX} and N_{CPICH} are also evaluated by taking a sliding time average of 6 min for all the measurements in agreement with the ICNIRP exposure guidelines⁽¹⁾.

Fig. 4 shows the cumulative distribution function (CDF) of the measured realistic values of the 99th percentile of N_{TRX} and N_{CPICH} for the GSM900, GSM1800, UMTS, and HSDPA technologies in Belgium. Clearly, all realistic values are lower than the theoretical maxima of Table 1 for the various technologies. The realistic values in Table 1 are obtained by taking the maximum and the median values of the CDFs of these realistic 99-percentile values in Fig. 4.

In France and in Belgium, the results of Table 1 show that the realistic maximal N_{TRX} in urban zones for GSM1800 (4.0 in France and 4.3 in Belgium, no averaging) is found higher than for GSM900 (3 in France and 4 in Belgium). This result was expected because the GSM1800 network is used as a reinforcement network to increase the GSM900 capacity. Therefore, N_{TRX} in a GSM1800 network is larger than in a GSM900 network in urban zones. This is not the case in rural zones, because GSM900 (e.g., in Table 1 maxima of 4.0 and 3.4 for GSM900

versus 3.0 and 2.7 for GSM1800, in France and Belgium, respectively) is preferred due to the propagation performances of the 900 MHz carrier in this environment and also because GSM900 was deployed first and no more capacity is needed in rural environments. This explains why the maximal N_{TRX} found for GSM1800 is smaller in rural than in urban zones. Also for the theoretical maxima these conclusions can be drawn.

Operators in France and in Belgium use UMTS most of the time for voice communications while HSDPA is used for data. UMTS and HSDPA are very similar in terms of signal characteristics and radio access interface. However, they are different in terms of power allocation. In fact, in HSDPA systems, all the power is allocated to one user equipment at a time, which explains why the N_{CPICH} for HSDPA is higher than UMTS in Table 1. Moreover, the theoretical values for HSDPA are higher in Belgium than in France, explaining the highest *realistic* values in Belgium for HSDPA.

The values for UMTS are the highest in France, because of the higher population and also because of the network optimization. Note that in Belgium, the UMTS network is not yet deployed as a GSM network, which is the reason for higher realistic values for GSM900-GSM1800 in urban areas in Belgium than in France.

Similar conclusions can be made in the two countries for both urban and rural areas: the maximal equivalent TRX and CPICH values in a realistic environment demonstrate that a full traffic situation is not reached in reality.

B. Weekdays versus weekend days

In Belgium, for each site, measurements were performed on weekdays and weekend days. Table 2 lists their median values of the 99% value for $N_{\text{TRX}}/N_{\text{CPICH}}$. Fig. 5 compares the CDFs for GSM900 in urban zones.

The median values are very similar for all types of technology in an urban environment for both weekdays and weekend days, in general only slightly higher values are obtained for weekdays (see also Fig. 5 for GSM900). Thus, realistic maximal traffic in urban environments does not depend much on the day of the week. In rural environments (Table 2), the N_{CPICH} values for HSDPA are higher on weekdays (4.9) than on weekends (3.8), indicating that here more data traffic is present on weekdays.

C. Comparison of the Maximal Daily Electric Field Value Using Different Methods

In this section, three methods are presented and compared to find the realistic scaling factors, in order to extrapolate an instantaneous measurement to the maximal value possible over a day.

1) Comparison of the Erlang and 3-Gaussian methods

The scaling factors of Fig. 3 for both methods as function of the time show a similar trend (for GSM900 and GSM1800). Lowest scaling factors (corresponding to highest measured instantaneous electric field values) can be found between noon and evening. Then, the scaling factors are for both methods lower than 1.4. Between 9:00 am and noon both methods have a decreasing scaling factor but the scaling factor based on the Erlang data gives higher values. The scaling factor based on the Erlang data is only considered during normal working hours while the scaling factor based on the 3-Gaussian model is given for the whole day. One has to

remark that the scaling factors to extrapolate instantaneous measurements to the maximum possible value over the day depend on the traffic pattern of the mobile phone users and can change over time. Consequently, the values must be evaluated at regular time intervals.

2) *Extrapolation for an instantaneous measurement with the different proposed methods*

In Table 3, a comparison of the different methods to calculate the maximum electric-field value can be found for a realistic long-term measurement, an example of a GSM signal, performed in Belgium. Both the instantaneous electric-field value during 24 hours and the pilot signals were measured. E_{\max}^{true} is the maximum measured electric-field value during 24 hours. The maximum calculated electric-field value E_{\max}^{calc} is also assessed using the different methods proposed in this paper. The first method is based on the extrapolation method mentioned in CENELEC⁽³⁾. The scaling factor is determined in three different ways: (i) using the real number of traffic channels TRXs for the specific site provided by the operators, (ii) using the equivalent number of TRXs based on the 3-Gaussian method (see Table 1), and (iii) using the number of TRXs mentioned in ANFR. The BCCH is not constant over time⁽⁴⁾, so we have chosen the mean value of the BCCH over 24 hours to perform the extrapolation. The second and third method are based on the scaling factors of the Erlang data⁽⁶⁾ and of the 3-Gaussian method⁽⁷⁾. The scaling factors (SF_{Erlang} and $SF_{3-Gaussian}$) are determined as a function of time to rescale the momentary total measured electric field value (measured at 11:00 am in our example). For the first method, a dedicated measurement equipment to measure the pilot signals is required while the total measured electric field, used for the second and third method, can be measured using a simple spectrum analyzer. The results are summarized in Table 3. In this table, the deviations Δ between the realistic maximum and the calculated maximum electric field are also listed:

$$\Delta = 20 \log \frac{E_{\max}^{calc}}{E_{\max}^{true}} \text{ (dB)} \quad (4)$$

The results of Table 3 confirm that the CENELEC method⁽³⁾ overestimates the real exposure (+1.7 dB to 5.7 dB), which is a high value compared to the proposed methods. The results found with the maximal N_{TRX} given from the operator (0.27 V/m corresponds to a full traffic situation as the maximal known N_{TRX} is used at this location) confirm that a situation with a full traffic is not reached in reality at this given location as the maximal real value found over 24 hours is only about 0.21 V/m. For the CENELEC method, extrapolation using the 99-percentile value (3-Gaussian method), gives lowest deviations (an overestimation of 1.7 dB). The methods proposed in^(4, 6, 7) give a better assessment of the maximal electric field value from an instantaneous measurement (only +0.4 dB to +0.6 dB for this example).

Finally, Table 3 compares also the electric-field values of the different methods with the ICNIRP reference levels⁽¹⁾. Therefore, the exposure ratio (*ER in* in %) of a signal is defined as the ratio in % of the obtained electric-field value to the corresponding ICNIRP reference level⁽¹⁾ for the general public. The percentages in Table 3 are much lower than 100%, indicating compliance with the ICNIRP guidelines. The 3-Gaussian and Erlang methods give $ER = 0.5\%$, which agrees very well with the true maximal ER value of 0.5%. The CENELEC method gives ratios up to 1%, thus an overestimation of a factor 2 is here possible. If exposure values would be close to the ICNIRP reference levels or regional limits, this overestimation can result in non-compliance while in reality compliance would be obtained.

IV. CONCLUSIONS

In this paper, the influence of the temporal daily exposure to GSM, UMTS, and HSDPA is investigated. Temporal variations and traffic distributions are compared in two

different countries, France and Belgium. The electric-field amplitude varies because it depends on the environmental changes and the traffic.

The number of actual traffic channels N_{TRX} and N_{CPICH} evaluated for GSM and UMTS, respectively, are determined in the two countries. Similar conclusions are found in the two countries for both urban and rural areas. The maximal N_{TRX} in GSM1800 is higher than the one of GSM900 in urban zones. This is not the case in rural zones, because GSM900 is preferred due to the propagation performances of the 900 MHz carrier in this environment. The maximal equivalent TRX and CPICH values found in a realistic environment demonstrate also that a full traffic situation is never reached in reality, and that the CENELEC method (worst-case assessment) overestimates the real exposure.

The Erlang and 3-Gaussian methods to assess the electric field exposure at a time instant from the electric-field measurements at another time instant, and to estimate the maximum electric-field value over a day from an instantaneous measurement are compared. These methods are also compared with the CENELEC method. Again, the CENELEC method overestimates the real exposure much more compared to the proposed methods.

Future research should focus on the temporal evolutions of LTE (long term evolution), which is recently launched in several countries.

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Table 1: Median and maximal values for the number of equivalent TRX ($N_{TRX,99\%}$) and CPICH ($N_{CPICH,99\%}$) for GSM, UMTS, and HSDPA in urban and rural zones (in France and Belgium).

Table 2: Comparison of median values of equivalent TRX ($N_{TRX,99\%}$) and CPICH ($N_{CPICH,99\%}$) for GSM, UMTS and HSDPA on weekdays and weekend days (for the different operators at each site in urban and rural zones in Belgium).

Table 3: Real and calculated maximal electric field values determined with different extrapolation methods and deviation Δ between true and calculated value for a GSM900 signal (measurement performed in Belgium).

Figure 1: Block diagram of the measurement procedure for temporal RF base station exposure assessment.

Figure 2: Electric field (V/m) of BCCH and TRX channels of GSM900 signal (396 traces during 24 hours).

Figure 3: Scaling factor based on Erlang for GSM900 and GSM1800 signals (median for all sites during working hours) and based on the 3-Gaussian method for GSM900, GSM1800, UMTS, and HSDPA.

Figure 4: Cumulative distribution function (CDF) of the 99% extrapolation factor for all sites in urban areas in Belgium (6 minutes averaging).

Figure 5: comparison of CDF of the 99% extrapolation factor on weekdays and weekend days for all sites in urban areas for GSM900 (Belgium, 6 minutes averaging).

			France		Belgium			
			Urban	Rural	Urban	Rural		
$N_{\text{TRX},99\%} / N_{\text{CPICH},99\%}$			Max	Max	Max	Median	Max	Median
N_{TRX}	Theoretical		6.0(*)	6.0(*)	5.0	3.0	4.0	3.0
GSM900	Realistic	No averaging	3.0	4.0	4.0	2.4	3.4	2.5
		6 min. averaging	2.36	3.2	4.0	2.4	3.4	2.1
N_{TRX}	Theoretical		8.0(*)	8.0(*)	8.0	2.0	4.0	3.0
GSM1800	Realistic	No averaging	4.0	3.0	4.3	2.6	2.7	2.2
		6 min. averaging	2.7	2.2	4.3	2.5	2.3	2.0
N_{CPICH}	Theoretical		10(*)	-	3.9	3.9	-	-
UMTS2100	Realistic	No averaging	5.0	-	2.3	2.1	-	-
		6 min. averaging	4.4	-	2.3	2.1	-	-
N_{CPICH}	Theoretical		-	-	20.0	14.8	20.0	15.0
HSDPA	Realistic	No averaging	14.0	-	18.7	7.9	9.8	5.4
		6 min. averaging	10.2	-	17.8	7.3	8.3	5.2

(x)* = general value recommended by ANFR

Table 1

$N_{\text{TRX},99\%}$		Weekday	Weekend day
Urban	GSM900	2.2	2.2
	GSM1800	2.5	2.3
	UMTS2100	2.1	2.0
	HSDPA	5.0	5.3
Rural	GSM900	2.1	2.0
	GSM1800	2.2	1.9
	UMTS2100	-	-
	HSDPA	4.9	3.8

Table 2

Methods of calculation of the E_{\max} for the measured site		E_{\max} (V/m)	Δ (dB)	ER (%)
Max over 24h	E_{\max}^{true}	0.210	-	0.5
CENELEC method	E_{\max}^{calc} based on BCCH and $N_{\text{TRX,realistic}}$ (given from the operator for this site)	0.270	2.2	0.7
	E_{\max}^{calc} based on $N_{\text{TRX,99\%}}$ found with the 3-Gaussian method	0.250	1.7	0.6
	E_{\max}^{calc} based on worst-case, (N_{TRX} given from ANFR)	0.410	5.7	1.0
Erlang method	E_{\max} based on SF_{Erlang}	0.224	0.55	0.5
3-Gaussian method	E_{\max} based on $SF_{3\text{-Gaussian}}$	0.221	0.44	0.5

Table 3

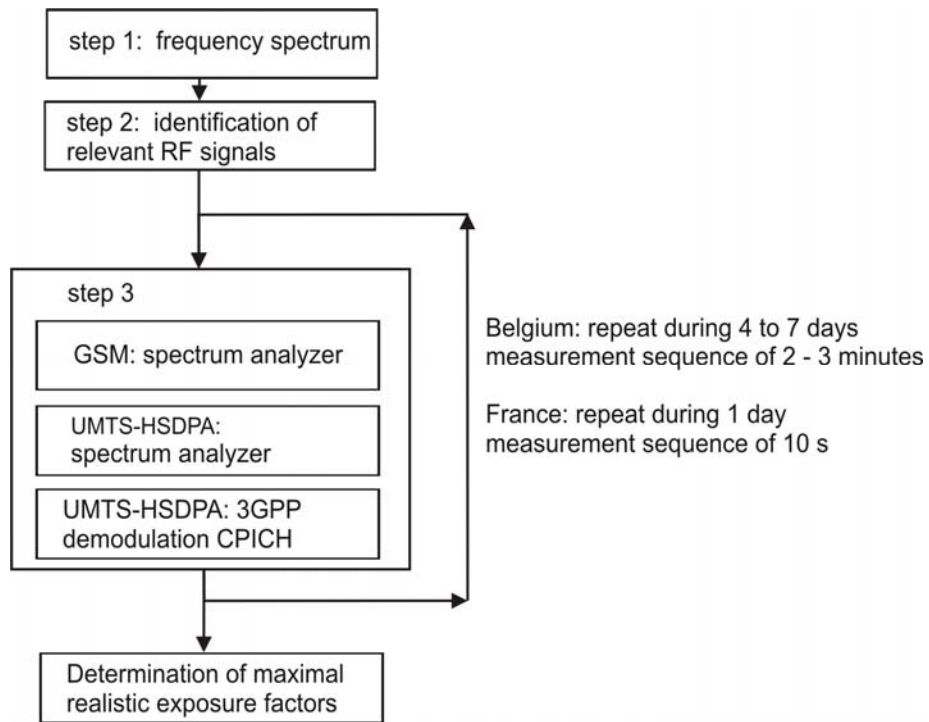


Figure 1

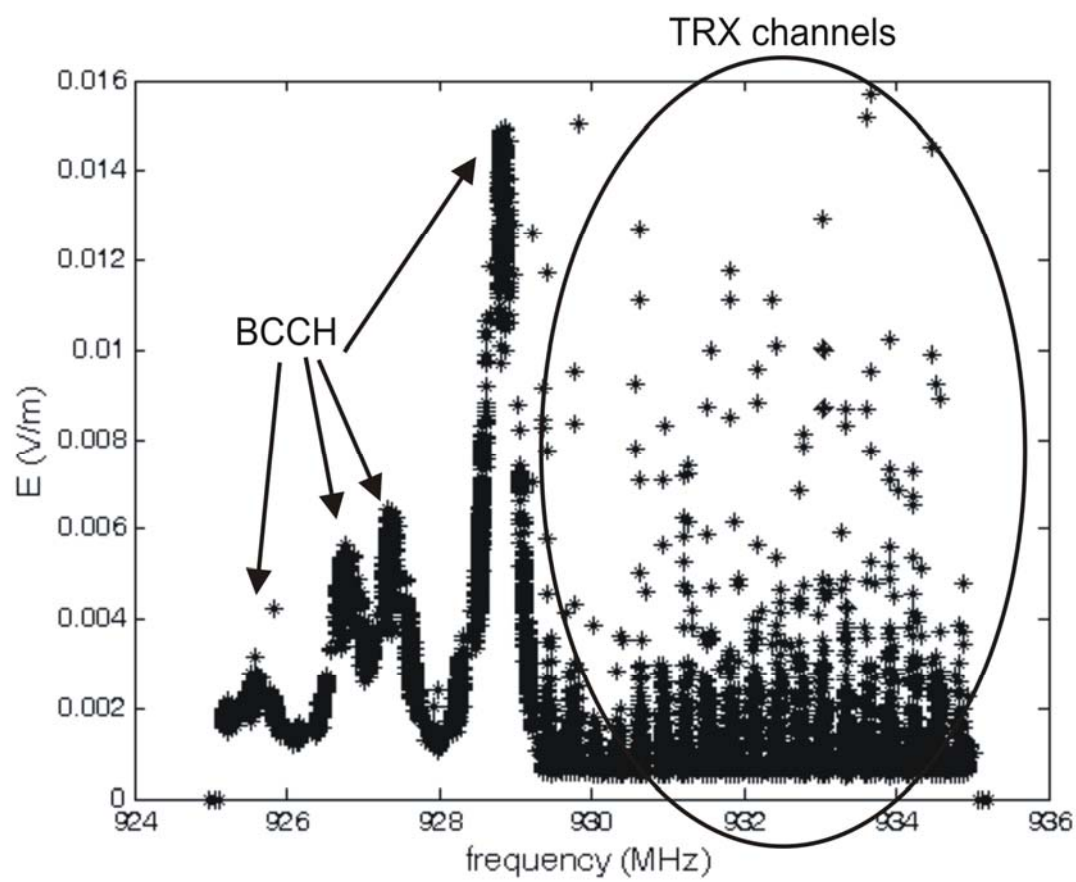


Figure 2

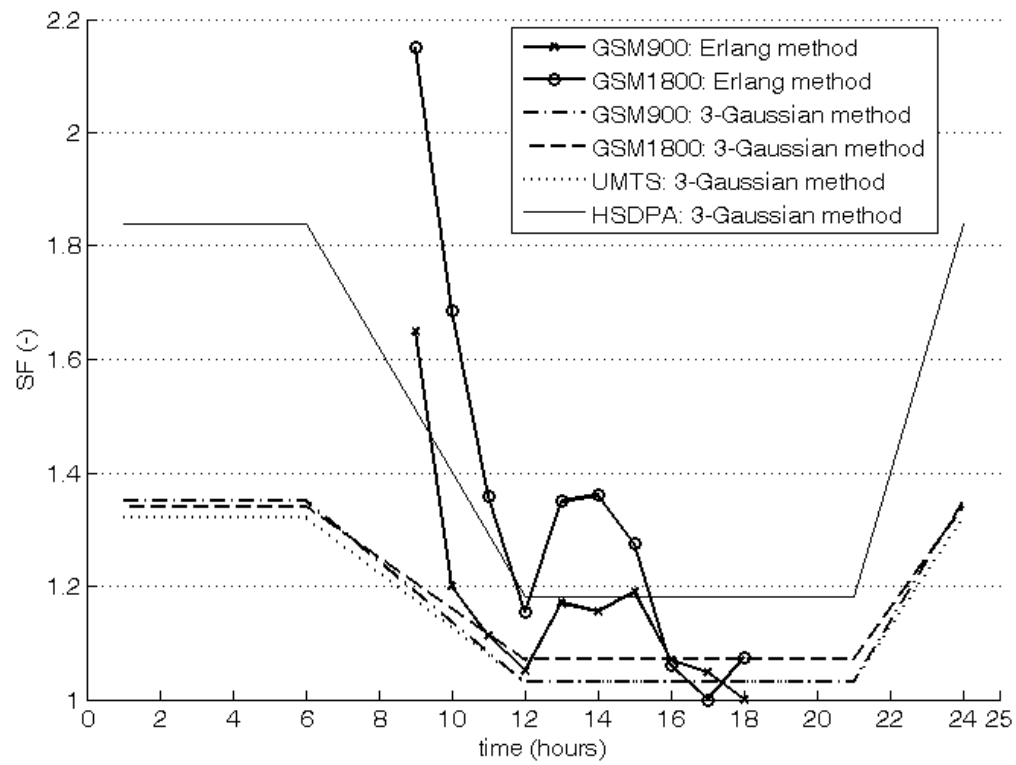


Figure 3

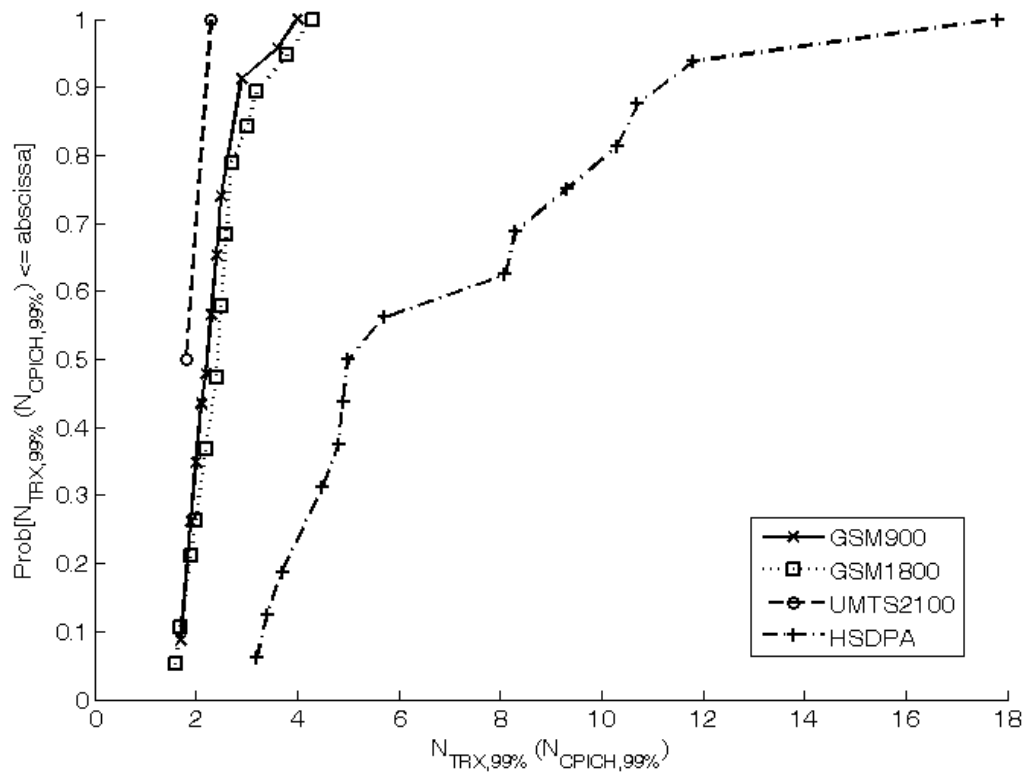


Figure 4

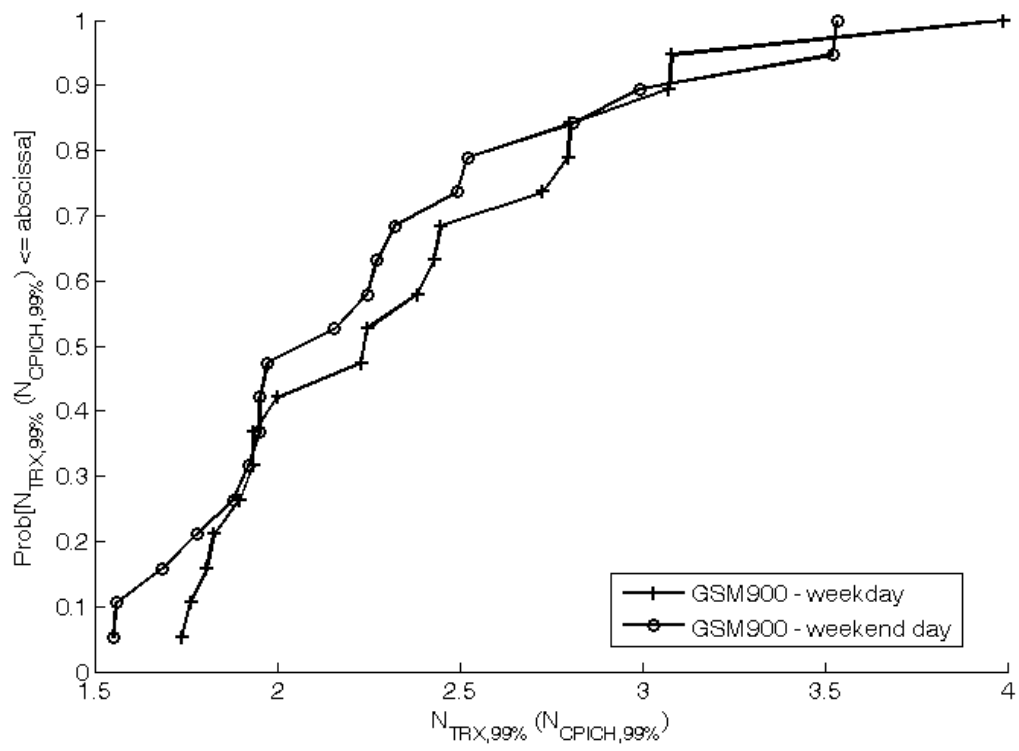


Figure 5